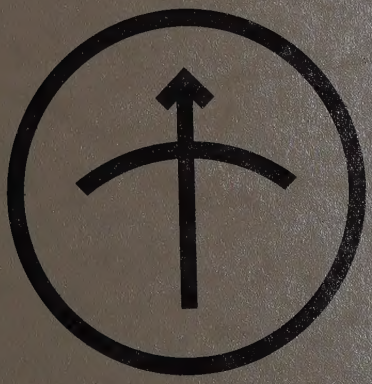
MODEL 505
STANDARD TEST SET FOR TRANSISTORS

Operating INSTRUCTIONS



MEASUREMENTS

A McGRAW-EDISON DIVISION

BOONTON NEW JERSEY

MODEL 505
STANDARD TEST SET FOR TRANSISTORS

Operating INSTRUCTIONS

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BOONTON NEW JERSEY

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Additional information with regard to the applications and maintenance of this equipment will be available from time to time. Users of the Model 505 are urged to discuss their problems with us and to suggest such modifications as might make the instrument more adaptable to their special requirements.

Maintenance difficulties should be reported to Measurements Corporation before proceeding with actual repairs, since, through our familiarity with the instrument, we are able to suggest the appropriate repair procedure.

Engineering Department

MEASUREMENTS CORPORATION

Boonton, New Jersey

U. S. A.

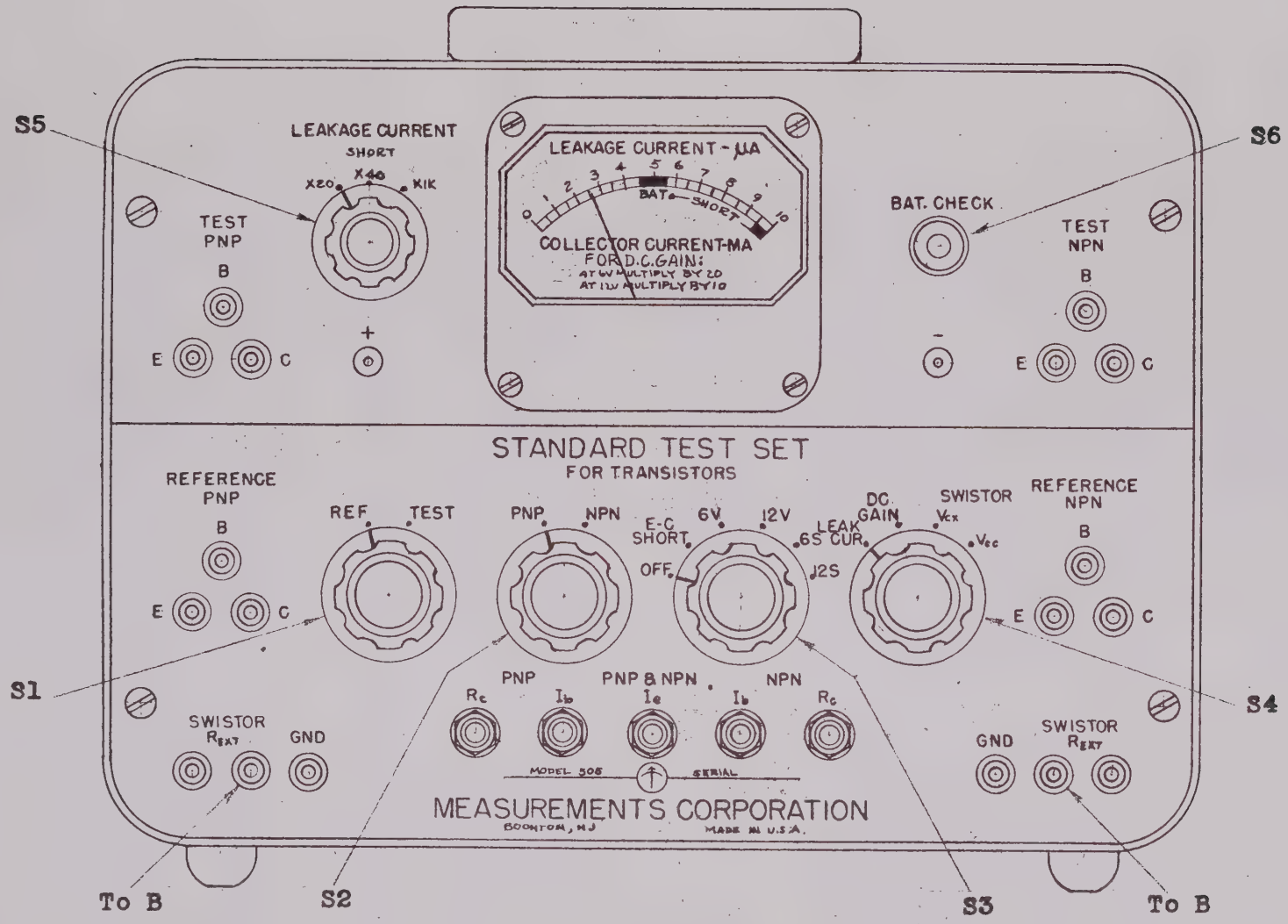


Figure 1. Front View of Model 505 Standard Test Set for Transistors.

CHAPTER 1

INTRODUCTION

SECTION I

GENERAL

1. SCOPE OF MANUAL

a. This manual describes the basic operation, construction, and maintenance of the Model 505 Standard Test Set for Transistors. Following the text of the manual are appendices. Appendix I describes the recommended procedure for preparing the instrument for prolonged storage or reshipment. Appendix II contains the Identification Table of Replaceable Parts, listing reference symbols, name and description, and drawing number of each part required for maintenance. Appendix III is a bibliography. Appendix IV contains the definitions of the technical terminology as used in this manual. Appendix V is a recapitulation of the procedure for making basic measurements on transistors. Two copies of Appendix V are included so that a copy may be removed for the convenience of the operator.

SECTION II

DESCRIPTION AND DATA

2. GENERAL

a. The Model 505 Standard Test Set for Transistors, (Fig. 1), is used for multiple testing of PNP and NPN small-signal, medium-power, and switching (computer) transistors. It can also be used for testing bilateral or symmetrical transistors. The design is such that the basic instrument measures important junction transistor parameters on a direct-current basis.

b. The Model 505 is portable. It consists of necessary programing controls, a calibrated current meter, and a biasing source in a compact container.

(1) The basic instrument is used for:

(a) Detection of short-circuited emitter-collector junctions with the base open-circuited.

(b) Measurement of collector-to-emitter "leakage current" to a maximum value of 10 ma, in three current ranges, for the common-emitter transistors. Collector-to-base leakage current may be measured by following the procedure of Para. 26 a.

(c) Measurement of collector current to a maximum value of 10 ma, or measurement of intrinsic transconductance, $G_m = .039\ I_c$ (where I_c is in milliamperes). (See Para. 20).

(d) Measurement of d-c gain (see Para. 20), over the range of 0 to 200, or as calibrated, since base current is established internally at two values: 50 μA at 6 volts; 100 μA at 12 volts.

(e) Measurement of incremental current gain. (See Para. 21).

(f) Measurement of output impedance ($\frac{1}{h22e}$) of the common-emitter transistor. (See Para. 22).

(g) Selection of transistors whose characteristics meet required device specifications, or rejection of units whose characteristics are outside of device specifications, by comparison with a "Reference" or "Bogey" unit whose characteristics meet the required specifications.

(h) Selection of matched pairs of audio or push-pull output transistors, by comparison with a "Reference" unit if desired. (See Para. 25).

(i) Measurement of emitter forward resistance, r_e. See Para. 23).

(2) The Model 505, in conjunction with suitable collector load and base biasing resistors, and an externally available d-c VTVM (such as Measurements Model 62) can be used for:

(a) Measurement of the "collector saturation voltage", sometimes called V_{cs} or V_{cx}, of switching transistors operating in the common-emitter configuration.

(b) Measurement of "Saturation Current Gain". (See Para. 24).

3. TECHNICAL CHARACTERISTICS

A. Physical Characteristics.

(1) Multiple test positions for junction PNP and NPN small-signal, medium-power, and switching transistors.

(2) Programing selectors operating from left to right to select test position, transistor type, power, and desired function.

(3) Jacks are provided for monitoring of collector, base and emitter circuits with external metering devices.

B. Direct-Current Characteristics.

(1) Panel Meter. (D'Arsonval type)

(a) Accuracy is approximately 5% of full-scale reading.

(b) Measures collector-to-emitter leakage current, I_{ceo}, of common-emitter transistor, up to a maximum of 10 milliamperes in three steps.

(c) Measures collector current, I_c, of common-emitter transistor up to a maximum of 10 milliamperes.

(d) Indicates $G_m = .039$ (Ic) mhos where Ic is in milliamperes.

(e) Measures d-c gain, sometimes called d-c Beta, or "large-signal gain".

$$(B = \frac{Ic - Iceo}{Ib} \quad \text{or} \quad B = \frac{Ic}{Ib}$$

from 0 to 200, or as calibrated.

(f) The meter is switched out of the circuit for measurements of saturation parameters of switching transistors.

(g) Indicates by a test switch, the condition of the internal resistance of the battery power supply.

D. Power Source.

(1) 6-volt d.c. and 12-volt d.c. normally supplied by dry batteries.

(2) External power supply may be employed.

4. COMPONENTS SUPPLIED

a. See Table I. Table of Components.

TABLE I. TABLE OF COMPONENTS

Quan.	Description	Case Dimensions			Unit Weight	Volume Cu. Ft.
		Height	Width	Depth		
1	Model 505 Standard Test Set for Transistors.	10"	14"	7-1/4"	11.2 lbs.	0.6
1	Manual of Operating Instructions.					
2	Type F4BP 6-volt dry batteries.				1.4 lbs. ea.	
1	Plug, PL-68					

5. EXPORT PACKAGING

a. For export, the Model 505 is packed in a wooden box.

TABLE II. EXPORT PACKAGING DATA

No. of Packages	Case Dimensions			Weight	Volume Cu. Ft.
	Height	Width	Depth		
1	17"	22"	17"	50 lbs.	3.7

CHAPTER 2

OPERATING INSTRUCTIONS

SECTION I

SERVICE UPON RECEIPT OF EQUIPMENT

6. UNPACKING

a. Take care when unpacking or handling the instrument. Follow the procedure outlined below for unpacking the instrument.

(1) Place the packing case in a location where it can be opened easily.

(2) Follow the instructions for slitting the carton and remove the filler as printed on the label on the carton. Extract nails if instrument is packed in a case.

7. PRELIMINARY PRECAUTIONS

a. Inspect the instrument for damage during shipment.

b. Batteries are supplied with this instrument and are connected so that the instrument is ready for use.

CAUTION:

If the instrument is to be stored for more than 6 months, the batteries should be removed to prevent the possibility of corrosion by battery chemicals. See paragraph 36C for battery replacement.

Determine that all switches S1, S2, S3, S4, S5 and S6 in Figure 1 operate satisfactorily. All switches, except BAT. CHECK switch, are rotary switches with positive detent action. The BAT. CHECK switch, S6, is a two-position, non-locking, lever-type switch.

SECTION II

CONTROLS AND INSTRUMENTS

8. TEST POSITIONS

a. The Model 505 has four positions on the front panel for multiple testing of transistors (See Fig. 1). Each position has three binding posts - one for emitter (E), one for base (B), and one for collector (C). Transistors can be connected directly to these posts, or adapters can be plugged into the posts and transistors can be connected to the adapters. The left half of the panel is used for testing PNP low and medium-power junction transistors. The right half of the panel is used for testing NPN junction transistors.

b. One of the left-hand positions is labeled TEST PNP and the other is labeled REFERENCE PNP.

c. One of the right-hand positions is labeled TEST NPN and the other is REFERENCE NPN.

d. Either, or both positions can be used for testing transistors. This multiple arrangement facilitates comparison of a transistor connected to the TEST position with a transistor connected to the REFERENCE position.

9. SELECTOR CONTROLS

a. Test sequences are programed by means of selector controls, S1 thru S6, on the front panel. The operating sequence is simple.

b. SELECTOR Switch S1 on the left-hand side of the identification plate selects either the REFERENCE or TEST position and programs it to the bias supply and meter.

c. SELECTOR Switch S2 on the left-center side of the identification plate selects the transistor type being tested: PNP on the left half of the panel, or NPN on the right half.

d. SELECTOR Switch S3 on the right center side of the identification plate applies POWER. It programs the biases to the transistor in proper sequence. Position 1 is OFF; position 2 tests transistors for high leakage or short-circuited emitter-to-collector junctions, as indicated by the pointer deflection to the red arc or solid red area on the meter dial, when S4 is in the LEAKAGE CURRENT position and S5 is in the SHORT position. Positions three and four furnish 6 and 12 volts of proper polarity for the tests. The 6S and 12S positions program the supply voltage to the test positions for measurements on switching, or computer, transistors, and disable the panel meter during these tests since an external d-c VTVM and/or current meters are used for these measurements. See paragraphs 24 and 33.

e. SELECTOR Switch S4 on the right side of the identification plate is the function selector. The functions, from left to right are LEAK CUR., D.C. GAIN, V_{cx} and V_{cc}. LEAK CUR. refers to collector-to-emitter leakage, D.C. GAIN refers to the d-c gain or large signal gain of a common-emitter stage, V_{cx} refers to the saturation voltage characteristic, while V_{cc} is the collector supply voltage.

f. SWITCH S5 on the left side of the panel meter is used for checking shorts and leakage current. This switch has 3 positions. The normal position of this switch (Fig. 1) is in the SHORT - X40 position when S4 is on LEAK CUR. The X20 position is used to increase meter sensitivity when leakage currents are small for low-gain PNP transistors. The X1K position is used when measuring leakage currents of germanium power transistors or small-signal transistors at high ambient temperature.

g. SWITCH S6 on the right side of the panel meter is used for BAT. CHECK. When this spring-loaded switch is depressed, the meter pointer should deflect into the solid area marked "BAT". If deflection is below this area, batteries should be replaced.

h. The panel meter is used for checking the battery, BAT., for indication of LEAKAGE CURRENT, COLLECTOR CURRENT, G_m, and D.C. GAIN of transistors.

10. POWER

a. Power is supplied by two batteries (type F4BP or equivalent). Both 6 and 12 d.c. volts are provided. See Para. 37.

b. The red test point marked "+" on the panel is the circuit power return point for PNP transistors, and is connected to the positive side of the battery.

c. The black test point marked "-" on the panel is the circuit power return point for NPN transistors, and is connected to the negative side of the battery.

11. SWITCHING TRANSISTOR TERMINALS

a. Binding posts labeled SWISTOR R_{EXT} are provided for connecting an external decade box for determining the proper value of base biasing resistor, for PNP and NPN switching transistors.

b. An external collector load resistor, R_C, preferably a decade box, must be inserted in the phone jack labeled R_C for the measurement of switching transistor characteristics, such as collector saturation voltage.

c. PNP switching, or computer transistors are placed in the PNP test positions and NPN switching transistors are placed in the NPN test positions.

d. Collector-saturation voltage measurements are made by connecting an external d-c VTVM, such as Measurements Model 62, between the appropriate collector binding post marked "C" and the red circuit return test point marked "+" for PNP transistors, or to the black circuit return test point marked "-" for NPN transistors. Paragraph 24 and Fig. 4 show the method of measurement in detail.

12. MONITORING JACKS

a. Five phone jacks are provided on the panel for monitoring emitter, base and collector circuits with external metering devices. The type PL-68, three conductor plug only can be used in these jacks. Use of these phone jacks gives the operator an additional "degree of freedom" in making measurements.

b. From left to right these panel jacks are labeled R_c and I_b for PNP transistors; I_e for both PNP and NPN units; and I_b and R_c for NPN transistors. (See Fig. 1).

c. An external meter plugged into the appropriate jack labeled I_b via a PL-68 plug will read base bias current.

d. An external meter plugged into jack labeled I_e will read emitter current of the transistor being tested whether it is a PNP or an NPN unit.

e. Externally available components, such as a decade box for collector load resistor, R_c, may be inserted in these jacks in order to set up tests for other transistor parameters such as V_{cx}. An external meter can be plugged into the appropriate R_c jack to monitor the current in that portion of the circuit.

SECTION III

OPERATION

13. INSTALLATION AND ADJUSTMENT

a. The Model 505 requires no permanent installation.

b. The Model 505 is portable. It can be operated in any position.

14. PRELIMINARY OPERATIONAL CHECKS

a. Turn selectors, S1, S2, S3 and S4 (Fig. 1) to their counterclockwise positions.

b. Check to be sure that selector S3 is in the OFF position.

c. Set switch S5 in the SHORT-X40 position.

d. Push the BAT. CHECK switch, S6, and note that the meter pointer swings midway up the dial to the marker labeled BAT. Replace batteries if the deflection is below this marker. See paragraph 36C for battery replacement.

e. Rotate selector S3 to the E-C SHORT position.

f. (See paragraph 18 before performing this test). Place a 4700 ohm (or 5000 ohm) resistor across the E-C binding posts of the REFERENCE PNP position. The meter pointer should swing to a position near three-fourths of full scale. This simulates a transistor with excessively high leakage current.

g. Leave the switches in the positions for the leakage test in "f". If the E-C binding posts of the REFERENCE PNP position are momentarily short circuited, the pointer will swing to the solid red marker labeled SHORT. This simulates a transistor with a short-circuited emitter-collector juntion.

15. OPERATING SEQUENCES

a. Place switch, S5, in the SHORT-X40 position. The basic measurements are made by operating selector switches S1, S2, S3 and S4 (see Fig. 1) from left to right across the panel.

b. The recommended procedure is as follows:

(1) Select test position. (S1)

(2) Select transistor type. (S2)

(3) Check for shorted E-C junctions, or excessive leakage currents. Place S3 on E-C SHORT, S4 on LEAK CUR. and S5 on SHORT-X40. If a transistor shows excessive leakage or a short, the additional tests below should not be made.

(4) Measure leakage. (Place S3 on 6V).

(5) Measure d-c gain, collector current or G_m. (Place selector S4 on D.C. GAIN).

(6) Measure other desired parameters with auxiliary components or test equipment.

16. SELECTION OF TEST POSITION

a. Connect low- or medium-power PNP transistors to either the REFERENCE PNP or TEST PNP binding posts.

b. Connect low- or medium-power NPN transistors to either the REFERENCE NPN or TEST NPN binding posts.

c. Place selector S1 in either the REF or TEST position corresponding to the binding posts to which the transistor is connected.

17. SELECTION OF TRANSISTOR TYPE

a. Place selector S2 on the PNP position for measurements on PNP transistors.

b. Place selector S2 on the NPN position for measurements on NPN transistors.

18. TEST FOR SHORT-CIRCUITED E-C JUNCTIONS OR EXCESSIVELY HIGH LEAKAGE CURRENT

a. Place switch S5 in the SHORT-X40 position.

b. Place selector S4 in the LEAK CUR. position.

c. Turn selector S3 to E-C SHORT. This applies 6 volts to the transistor in the test position selected according to paragraphs 16 and 17.

(1) The meter pointer will deflect to the solid red area labeled SHORT if the transistor has a dead short circuit between emitter and collector junctions. See Fig. 2(a).

(2) The meter pointer will deflect to a position somewhere on the red arc labeled SHORT if the transistor has a high leakage current due to a faulty junction, or due to a leak in the hermetically sealed case, or if the transistor is of the medium or high power germanium type. See Fig. 2 (b).

(3) Tests on a particular transistor should be discontinued immediately if the pointer comes to rest in the solid red area. Turn selector S3 to OFF and remove the transistor from the instrument. If the pointer comes to rest on the red arc near the solid red area, proceed with caution in making the additional tests.

(4) The pointer will stop below the red arc if the leakage current is nominal or satisfactory for germanium PNP transistors. * In this case, the next test step (paragraph 19) can be made. There will be no pointer deflection for nominal silicon NPN grown-junction small-signal transistors. Due to the nature of the semi-conductor, the nominal leakage current of silicon NPN transistors is usually less than 2 microamperes at room temperature. In this case, proceed to the next test step (paragraph 19).

(5) External meters should not be placed in the jacks when short-circuit tests are being made.

19. MEASUREMENT OF COLLECTOR-EMITTER LEAKAGE CURRENT WITH BASE OPEN

NOTE: See Para. 26 a. for Collector-Base leakage tests.

a. Place switch S5 in the SHORT-X40 position.

b. Place selector S4 in the LEAK CUR. position.

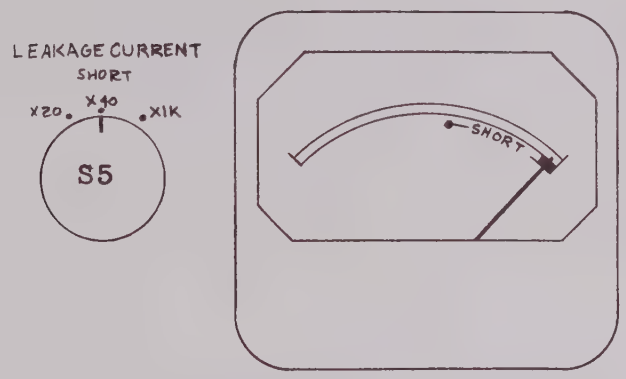
c. Turn selector S3 to the 6V position. This applies 6 volts to the transistor test position selected, as indicated in paragraphs 16 and 17. Leakage current is indicated in microamperes on the top scale of the meter. With switch S5 in the X40 position, the scale reading is multiplied by X40 to obtain the magnitude of the collector-to emitter leakage current of the common-emitter transistor with the base open.

d. If the leakage current is low (less than approximately 200 microamperes), the meter sensitivity can be increased by turning switch S5 to the X20 position. With S5 in the X20 position, the meter will read 200 microamperes full-scale. Always return S5 to the SHORT-X40 position after performing the above operation.

e. The leakage current of most small-signal silicon NPN grown-junction transistors is less than 2 microamperes at room temperature. When such values must be measured accurately, an external microammeter of suitable range can be plugged into either the I_e or R_c jack. If the leakage current is unstable, intermittent, or erratic, the transistor is unsatisfactory, and should not be used in any circuit.

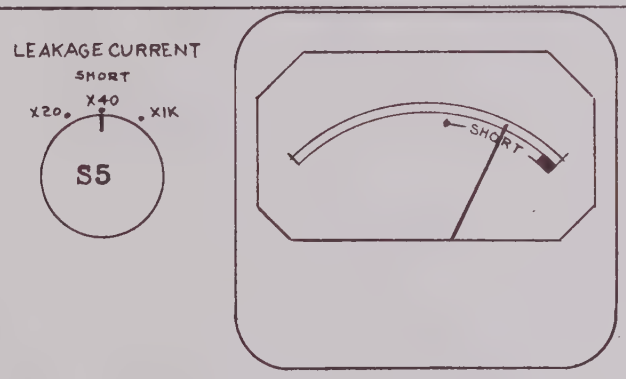
* (See Fig. 2)

Interpretation of panel meter indication for testing transistors for short circuited junctions, excessive, or nominal leakage current.

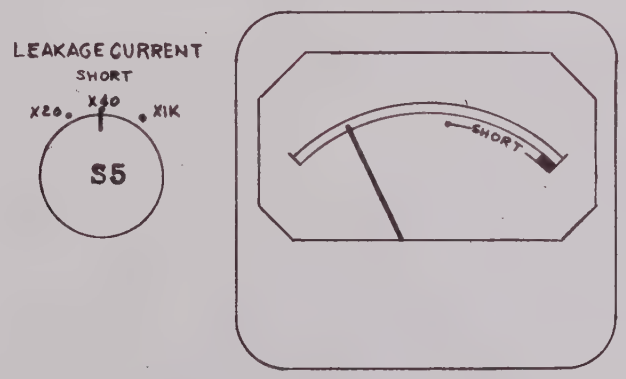


NOTE: SHORT tests are made with 6 volts and the collector current is limited to 400 micro-amperes by a 15,000 ohm resistor. Collector to emitter SHORT tests are made with the base open-circuited.

(a)
The pointer will deflect to the solid red area labeled "SHORT", if the transistor has a dead "short circuit" between emitter and collector.



(b)
The pointer will deflect to a position on the red arc labeled "SHORT" if the transistor has an excessively high leakage current.



(c)
The pointer will show no deflection or stop below the red arc if leakage current is "nominal".

Figure 2. Short and Leakage Meter Indications.

Base bias current read on an external meter plugged in I_b jack $= I_b = 48$ microamperes

$$\text{D-C Gain} = B = \frac{I_c - I_{ceo}}{I_b} = \frac{3000 - 120}{48} = 60$$

For an assumed value of base bias current of 50 microamperes and a collector current of 3 milliamperes, the D-C Gain, as read from the calibrated panel meter would be

$$B = \frac{3000}{50} = 60$$

(2) With selector S3 on 12V and selector S4 on D.C. GAIN, the following data are observed.

Collector Supply Voltage = V_{cc} = 12 d.c. volts

Collector Current read on the meter $= I_c = 6.2$ MA $= 6200$ μA

Leakage Current read on the meter per paragraph 19 $= I_{ceo} = 130$ μA

Base Bias Current read on an external meter plugged in I_b jack $= I_b = 97$ microamperes

$$\text{D.C. Gain} = B = \frac{I_c - I_{ceo}}{I_b} = \frac{6200 - 130}{97} \cong 62$$

(3) For $V_{cc} = 6$ d.c. volts, $G_m = (.039)(3) = 0.117$ mho

For $V_{cc} = 12$ d.c. volts, $G_m = (.039)(6.2) = 0.2418$ mho

21. MEASUREMENT OF "INCREMENTAL CURRENT GAIN"

a. Incremental Current Gain is defined as follows:

$$b = \frac{\triangle I_c}{\triangle I_b} \quad \text{when } V_{cc} \text{ is constant}$$

The incremental values of collector and base current may be read from a plotted $V_c - I_c$ characteristic curve for the common-emitter transistor, or measured as indicated in Figure 3, and paragraphs below.

b. An external meter of suitable range in series with a variable resistor is plugged into the appropriate I_b jack on the panel.

c. With the external resistor set at zero value, note the value of I_b on the external meter and the value of I_c on the panel meter.

d. Adjust the external resistor so it adds enough resistance to the circuit to change the values of both I_b and I_c. Note the new values of I_b and I_c.

e. Incremental Current Gain, b, is calculated as follows:

$$b = \frac{\Delta I_c}{\Delta I_b} = \frac{I_{c2} - I_{c1}}{I_{b2} - I_{b1}} \quad \text{when } V_{cc} \text{ is held constant}$$

22. MEASUREMENT OF LOW-FREQUENCY OUTPUT IMPEDANCE OF THE COMMON-EMITTER TRANSISTOR

a. The output impedance 1/h22e of the common-emitter transistor is essentially a resistance at low frequencies. The admittance h22e is defined as the slope of the $V_c - I_c$ characteristic curve of the common-emitter unit when the base current, I_b, is constant.

$$h_{22e} = \frac{\delta I_c}{\delta V_c} \cong \frac{\Delta I_c}{\Delta V_c} \quad \text{when } I_b \text{ is constant}$$

b. Neglecting the small reactive component at lower frequencies, the resistive component of output impedance is

$$\frac{1}{h22e} = \frac{1}{\frac{\delta I_c}{\delta V_c}} \cong \frac{\Delta V_c}{\Delta I_c} \quad \text{when } I_b \text{ is constant}$$

c. With selector S3 set at 6 volts and selector S4 on D.C. GAIN, record the value of I_c, measure the base current, I_b, with an external meter plugged into the appropriate I_b jack with a PL-68 plug.

d. Place a variable resistor, or decade box, of approximately 120,000 ohms in series with the I_b meter.

e. Move selector S3 to the 12-volt position and adjust the decade box in the I_b jack until the original value of I_b is obtained.

f. Record the new value of I_c.

g. An appropriate value of the resistive component of output impedance may be calculated from

$$\frac{1}{h22e} = \frac{\Delta V_c}{\Delta I_c} = \frac{12 - 6}{I_{c2} - I_{c1}} = \frac{6}{I_{c2} - I_{c1}}$$

23. MEASUREMENT OF EMITTER FORWARD RESISTANCE

a. Insert an external current meter of suitable range in the emitter-current jack, I_e. Set selector S3 to 6V and selector S4 to D.C. GAIN. Record the value of emitter current, I_e.

b. The emitter forward resistance, r_e, may be calculated from the relation.

$$r_e = \frac{25}{I_e} \quad \text{where } I_e \text{ is in milliamperes}$$

24. MEASUREMENT OF SWITCHING TRANSISTOR CHARACTERISTICS (Common Emitter Configuration)

a. Among important switching transistor characteristics that can be measured by using the Model 505, are Collector Saturation Voltage, V_{cx}, Collector Saturation Current, I_{csat}, and Base Bias Saturation Current, I_{bx}. The panel meter is disabled during these measurements, or when selector S3 is on 6S or 12S and selector S4 is on V_{cc} or V_{cx}.

b. Whenever the data is useful, Collector-to-Emitter Leakage Current, I_{cbo} and D-C Gain (large-signal gain), B, can be measured as indicated in paragraphs 19 and 20.

c. Turn selector S3 to OFF. For measurement of V_{cx}, I_{csat} and I_{bx}, connect a suitable value of load resistor, R_c, (values of 3000 to 10,000 ohms are used for practical measurements on many types of small-signal switching transistors) in series with a current meter of proper range by means of a PL-68 plug to the applicable R_c jack. Figure 4 shows the test setup and the graphical importance of the measurements. Connect a base biasing resistor, preferably a decade box of suitable value for driving the transistor into the saturation or "ON" state, in series with a current meter across the terminals labeled SWISTOR-R_{EXT}. The left-hand SWISTOR-R_{EXT} terminals are for PNP switching units. The center terminal (see call-out in Fig. 1) is internally connected directly to the transistor base.

Connect a d-c VTVM, such as Measurements Corp. Model 62, between the collector binding post of the transistor being tested and the red phone tip jack marked "+" for PNP units, or to the black phone tip jack marked "-" for NPN units.

d. Turn selector S4 to the V_{cc} position; turn selector S3 to the 6S or 12S position to apply collector supply voltage, V_{cc}, which can be read on the VTVM.

e. Turn selector S4 to V_{cx} to read the value of Collector Saturation Voltage on the VTVM. In general, V_{cx} should be less than 0.7 volt d.c. for satisfactory switching transistors.

f. Base bias current, I_{bx}, can be read on the meter in series with R_{EXT}, and Collector Saturation Current, I_{csat}, can be read on the meter in series with the collector load resistor in the R_c jack. (See Fig. 4).

g. The D-C Saturation Current Gain is given by

$$B_s = \frac{I_{csat} - I_{ceo}}{I_{bx}}$$

The Leakage Current, I_{ceo}, can be measured as indicated in paragraph 19.

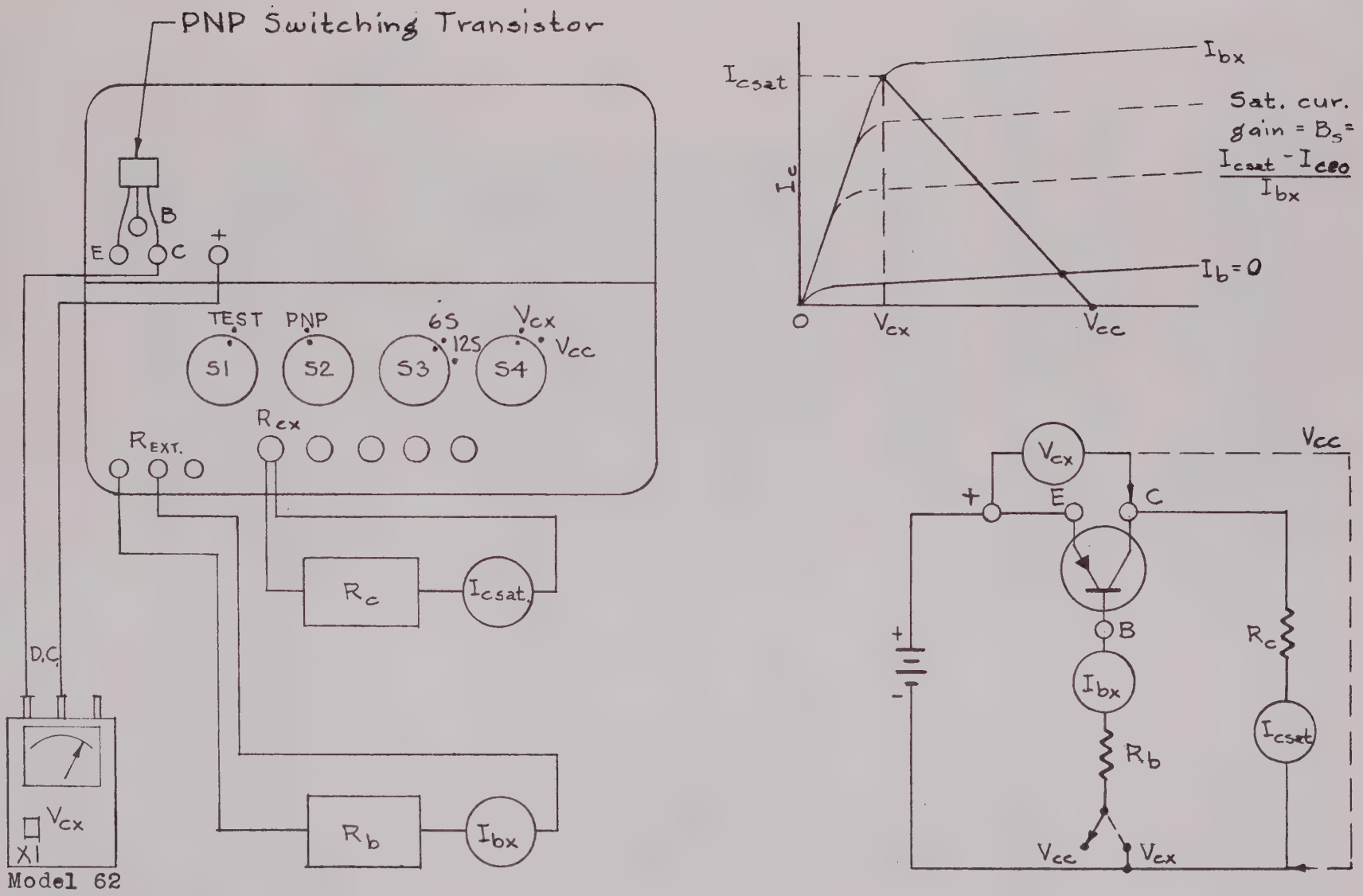


Figure 4. Measurement of Switching Transistor Characteristics.

The base bias resistor must be capable of supplying current to drive the switching (computer) transistor to the saturation or "on" region (see Fig. 4). Therefore, the base bias resistor across the SWISTOR-R_{EXT} terminals must satisfy the condition that

$$I_{bx} = \frac{I_{csat} - I_{ceo}}{B_s}$$

25. SELECTION OF MATCHED PAIRS OF TRANSISTORS

a. In many applications, such as audio push-pull output stages, "flip-flops", switching and computer systems, it is desirable to select pairs of transistors with matched d-c characteristics (matched pairs).

(1) Incoming or unknown transistors first are placed in the applicable "test" position and checked for shorted junctions and excessive leakage current per paragraph 18.

(2) One method is to place a "bogey" transistor or a transistor that meets the desired specification in the PNP REFERENCE or NPN REFERENCE test position, depending on its type. Then the leakage current and d-c gain of the incoming units are measured and compared to the "bogey" unit by moving selector S1 back and forth between the TEST and REFERENCE position when S4 is on LEAK CUR., and then on D.C. GAIN, until matched pairs are obtained.

(3) Another method is to tabulate leakage current, d-c gain, collector current, G_m, or r_e of incoming units. The tabulated deviations can be used by quality control, production, or standards groups, for selection of matched units, or to establish practical limits or tolerances in the spread of these characteristics, for production or statistical purposes.

26. ADDITIONAL MEASUREMENTS

a. Collector-to-Base Leakage Current Measurements.

(1) To measure I_{cbo}, the collector-to-base leakage current with the emitter open-circuited, connect the collector lead of the transistor to the "C" binding post, connect the base lead of the transistor to the "E" binding post, and leave the emitter lead of the transistor unconnected.

(2) Follow the procedure given in Para. 19 to make the leakage test.

b. Bilateral Transistors.

(1) The Model 505 can be used for measurement of the characteristics and parameters of bilateral transistors. By turning selector S1 back and forth between the two test positions, "matched pairs" can be selected.

(2) The basic procedure for measurement of LEAKAGE CURRENT and D.C. GAIN is outlined below.

(3) The emitter, E, and collector, C, of a bilateral transistor are interchangeable and the output signal can be taken from either electrode. Connect the bilateral transistor, in the normal configuration, i.e., use the emitter electrode as the emitter, the base as the base, and the collector as the collector, to the appropriate E, B, C binding post. Check for SHORTED JUNCTIONS, LEAKAGE CURRENT, and GAIN, as per paragraphs 18, 19 and 20. Then turn S3 to OFF and S4 to "LEAK CUR". Disconnect the transistor from the binding posts, and rotate it 180°, so that the physical positions of the transistor E and C electrodes are reversed. Reconnect the transistor to the binding posts so that the collector electrode, C, of the transistor is connected to the E binding post, of the Model 505, and the emitter electrode, E, of the transistor is attached to the C binding post of the instrument - the base electrode, B, of the transistor is still attached to the B binding post of the Model 505. Repeat the tests indicated in Paragraphs 18, 19 and 20, to check for SHORTED JUNCTIONS and to measure LEAKAGE CURRENT and D.C. GAIN, when the bilateral transistor is in this new configuration.

CHAPTER 3

MAINTENANCE INSTRUCTIONS

SECTION I

MAINTENANCE

27. GENERAL

a. The Model 505 is designed so that operational failures will be minimized. Routine preventive maintenace is not required.

b. Batteries should be removed from the instrument prior to prolonged storage or preparation for shipment.

c. During nominal daily tests on small-signal transistors, the battery life will be slightly less than the normal shelf life of the F4BP, or equivalent, battery.

28. CIRCUIT FAILURES

a. Damage to the meter or switches may result if the instrument is dropped. In this event, it is advisable to return the instrument to the factory for repairs, or to order the necessary replacement parts from Measurements Corporation.

b. If erratic operation of the Model 505 is indicated, the switches should be rotated to clean the contacts, and the contacts in the jacks should be cleaned and checked for continuity.

CHAPTER 4

EQUIPMENT USED IN CONJUNCTION WITH THE MODEL 505

SECTION I

ACCESSORIES

29. RECOMMENDED AUXILIARY EQUIPMENT

a. For normal use in checking for E-C shorts, leakage current, D-C Gain, Collector Current and G_m, no accessories are required.

b. For measurement of output impedance, the following are recommended:

(1) Three Type PL-68 phone plugs.

(2) Decade box with range of 0 to 500,000 ohms.

(3) Two multi-range current meters with full-scale ranges of 20 UA to 500 MA.

c. For measurement of the saturation voltage parameter, V_{cx}, of switching transistors, the following are recommended:

(1) Measurements' Models 62, 162 or 162-R, Vacuum-Tube Voltmeters.

CHAPTER 5

TECHNICAL SERVICE - MAINTENANCE INSTRUCTIONS

SECTION I

GENERAL

30. SCOPE

a. The purpose of this chapter is to acquaint operating and maintenance personnel with the theory of operation of the circuits in the Model 505.

b. Return the instrument to Measurements Corporation whenever repairs involving replacement of components in the metering circuits are necessary.

SECTION II

CONDENSED THEORY OF OPERATION

31. GENERAL

a. The Model 505 is a portable, battery operated instrument, of compact construction.

32. POWER SUPPLY

a. The power supply consists of two type F4BP, or equivalent, 6-volt batteries. See paragraph 36-c for installation or replacement of batteries. See Para. 37 for use of external power.

b. The condition of the batteries may be noted by depressing the BAT. CHECK switch, S6, and noting that the meter pointer deflects into the BAT marker on the meter dial. When the pointer falls below this marker, the batteries have reached the end of their useful life, and must be replaced.

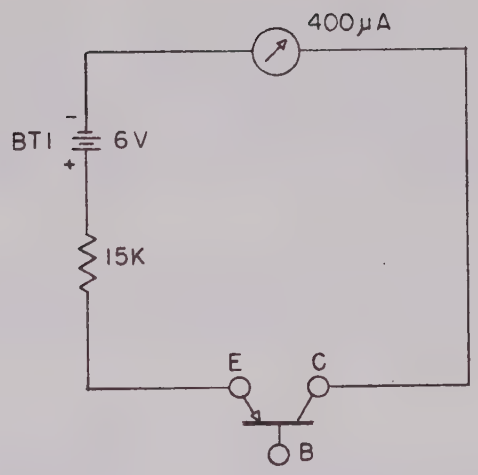
33. CIRCUITRY

a. The Model 505 uses no vacuum tubes. The basic circuits used for SHORT, LEAKAGE and GAIN tests are shown in Figure 5.

b. Testing of transistors in the common-emitter configuration is performed on a pre-programed basis by four primary selector switches, S1, S2, S3 and S4 on the front panel (see Fig. 1) and the test switch, S5, at the left of the meter.

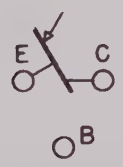
(a) E-C SHORT Test

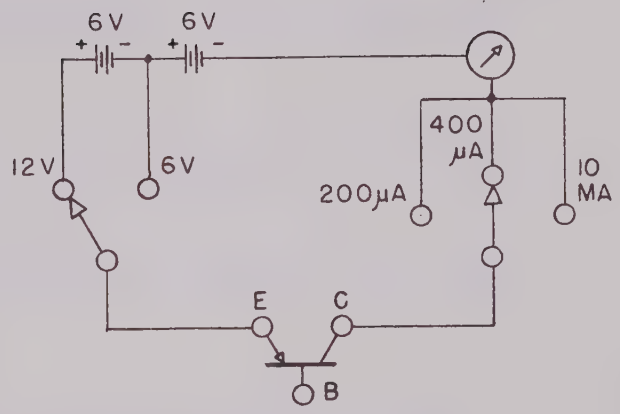
1. Maximum current is limited to 400 uA.
2. Test is made with 6 volts.



(b) LEAKAGE Test

1. C-E leakage with Base open normally measured.
2. To measure C-B leakage with Emitter open, connect transistor as shown below:





(c) GAIN Test

1. Base current is approximately 50 uA at 6 volts and 100 uA at 12 volts.
2. Meter reads 10 MA full-scale for GAIN tests.

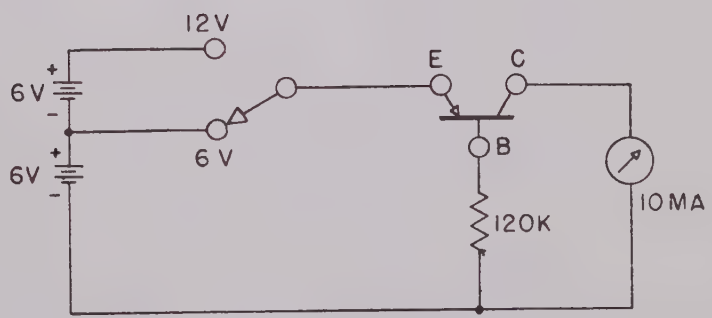


Figure 5 - Basic Circuits Used in Model 505
(Similar Circuits Used for NPN transistors.)

The leakage current scale reading is noted and multiplied by X40 to establish the magnitude of the collector-to-emitter leakage current with the base open of the common-emitter transistor.

If the leakage current is at the low end of the scale, meter sensitivity can be increased by placing switch S5 on the X20 position. Multiply the scale reading by X20 to obtain the magnitude of the leakage current. Switch S5 should be returned to the X40 position after such an operation. For temperature cycling tests or junction temperature data, switch S5 can be placed on the X1K position, to measure the increased leakage current as a function of ambient or junction temperature. With S5 on the X1K position, the meter will read leakage current to 10 milliamperes.

(2) Measurement of D-C Gain and Collector Current.

Placing selector S3 on 6V and selector S4 on D.C. GAIN, applies an internally-established value (approximately 50 microamperes) of bias current to the transistor base.

When a transistor is operated as a common-emitter stage, current gain occurs and there is a resultant increase in collector current. The panel meter measures collector current up to a maximum value of 10 ma. The meter is calibrated for direct reading of D-C Gain from 0 to 200.

Placing selector S3 on the 12V position, for transistors rated for this collector voltage, applies a bias current of approximately 100 microamperes to the base of the transistor. The panel meter measures collector current up to a maximum value of 10 ma. The meter is calibrated for direct reading of D-C Gain from 0 to 100 for this operating condition.

(3) Often it is desirable, to connect R, L and C components to a transistor test position, or necessary to monitor the currents flowing through a transistor. Components and meters of suitable range can be connected to transistors via the panel jacks. These jacks will accomodate only the PL-68 plug. Monitor emitter-current, I_e, for both PNP and NPN units by inserting a meter, attached to a PL-68 plug, in the jack labeled, I_e. Measure base bias current, I_b, by inserting a microammeter (100 microamp range is suitable for most tests) in the appropriate I_b jack. Monitor Collector Current by placing a suitable meter in the appropriate R_c jack.

(4) Measurement of Characteristics of Switching (computer) Transistors Operating in the common-emitter Configuration.

(a) This instrument has been designed so that measurements of switching (computer) transistor parameters, for a wide range of operating and environmental conditions are made with selector S3 on the 6S and 12S positions and selector S4 on the V_{cc} and V_{cx} SWISTOR positions. When selector S3 and S4 are on the above positions, the panel meter and the internal base biasing circuits are disabled. This is because the base biasing resistor must be chosen for a given transistor type to satisfy the conditions indicated in paragraph 24.

(b) For Switching Transistor measurements, the Model 505 may be used as follows:

Place selector S3 on the OFF position and selector S4 on LEAK CUR. Connect switching transistors to the desired test positions and turn selector S1 and S2 accordingly. Check transistors for shorts and excessive leakage per paragraphs 18 and 19. Then choose a collector load resistor, R_c, of suitable value (approximately 3,000 to 10,000 ohms); connect R_c in series with an externally available current meter of satisfactory range. Attach R_c and the meter to a PL-68 plug and insert the plug in the proper R_c jack. Connect a suitable value of base bias resistor, R_b, (or decade box) in series with a current meter of sufficient range between the two appropriate SWISTOR R_{EXT} posts. The center post (see call out Fig. 1 and paragraph 24) is connected to the base electrode of the transistor. Connect an external d-c VTVM, such as Measurements Corp. Model 62, between collector, C, of the transistor and circuit supply voltage return point (red test jack "+" for PNP, or black test jack "-" for NPN transistors).

Place selector S4 on V_{cc} and selector S3 on 6S, or 12S according to the rating of the transistor. The applied collector supply voltage, V_{cc}, will be indicated by the external d-c VTVM when placed on a suitable range. Since the collector load resistor, R_c, and the base bias resistor, R_{EXT}, are in the proper position, turning selector S4 to the V_{cx} position, will apply a bias current to the transistor base. This process switches the transistor from the OFF, or non-conducting state in the V_{cc} position, to the ON, or conducting state in the V_{cx} position (see Fig. 4 and paragraph 24). Collector saturation current, I_{csat}, and base saturation current, I_{bx}, are indicated by the current meters and collector saturation voltage, V_{cx} is read on the d-c VTVM that is connected between collector and circuit return point. Collector saturation voltage should be less than 0.7 volt. Saturation d-c current gain is given by

$$B_s = \frac{I_{csat} - I_{ceo}}{I_{bx}}$$

SECTION III

TROUBLE LOCATION

34. LOCALIZING THE TROUBLE

a. Trouble may be localized by making the preliminary operational checks and operational sequences described in paragraphs 14 and 15.

b. A current meter of suitable range attached to a PL-68 plug, may be inserted in the applicable panel jack to aid in localizing trouble. For example, if a phone jack is open, there will be no current flow in that part of the circuit.

35. REPLACEMENT OR ADJUSTMENT OF PARTS

a. Phone Jacks.

(1) Replacement of parts such as phone jacks, switches, and precision resistors can be achieved without affecting the performance of the instrument provided these parts are equivalent to the original parts. Replacement problems should be reported to Measurements Corporation.

SECTION IV

PRE-ADJUSTMENT PROCEDURE

36. TEST EQUIPMENT REQUIRED

a. Special test equipment is not required for checking the basic operation of the Model 505.

b. The only adjustment procedure recommended is the replacement of batteries or the connection of external batteries as outlined below.

c. Batteries are installed or replaced as follows:

(1) Loosen the four black filister-head screws on the edges of the front panel and pull the panel out of the case.

(2) Two type F4BP (or equivalent) batteries are employed. The battery compartment is at the rear of the chassis, and the polarities of the connectors are labeled on the terminal board. Install batteries, connect wires observing proper polarity, and fasten panel back in place.

(3) To use external batteries, remove the internal batteries (per paragraph 36-C). Attach wires, as required, of suitable length to the battery terminal board. These external wires may be passed through the hole (remove plug button) in the bottom of the instrument. Observe proper polarity, as marked on the terminal board in connecting the external batteries.

SECTION V

ADJUSTMENT PROCEDURES

37. GENERAL

a. The only adjustment (or replacement) procedure recommended, is the connection of external batteries or replacement of batteries, as outlined in paragraph 36-C.

b. Batteries BT1 and BT2 should be inter-changed from time to time to equalize their life.

c. The battery check is made by checking the condition of the 6-volt battery BT1. The meter is connected as a 12-volt meter (a 60,000 ohm resistor in series with the 200 microampere meter) in making the battery check. The meter will, therefore, read mid-scale in the BATT. region when checking the condition of BT1. If an external power supply exceeding 12 volts is connected to terminals 1 and 2 of the battery board, the meter will read off scale and will be overloaded if the BAT. CHECK switch is operated.

d. When POWER source voltages other than 6 volts and 12 volts are used, due consideration must be given to the resultant effect on the metered ranges of the instrument.

(1) The SHORT test utilizes the 6-volt battery, BT1, and a 15,000-ohm current-limiting resistor R4 with the meter shunted to read 400 microamperes full-scale on a collector-to-emitter short. If the voltage BT1 is decreased, the SHORT meter indication will decrease correspondingly; and if the voltage BT1 is increased the meter will be overloaded. The value of R4 may be changed in the same ratio as the change in BT1 if it is desired to preserve a correct SHORT indication.

(2) The LEAKAGE current ranges are not affected by a change in either BT1 or BT2 and remain at 200 microamperes for X20, 400 microamperes for X40 and 10 milliamperes for X1K.

(3) For GAIN measurements, the base current is limited by 120,000-ohm resistors to 50 microamperes at 6 volts and to 100 microamperes at 12 volts. Since the meter is shunted to 10 milliamperes for GAIN tests, the gain ranges are 200 and 100 respectively. If the voltage of BT1 and/or BT2 is changed, the GAIN ranges will change correspondingly.

APPENDIX I

STORAGE AND SHIPMENT

1. STORAGE

a. Remove batteries from instrument (see paragraph 36-C) and remove dust from controls and outer surface of instrument with a clean rag.

b. Wrap instrument in heavy wrapping paper and seal seams with gummed tape or similar adhesive.

c. Store in a dry place. If excessive humidity is unavoidable, place the instrument in a moisture-proof bag with a sufficient quantity of drying agent, such as silica gel, to insure a dry atmosphere.

d. When the use of container and dessicant is necessary, check the instrument at 6-month intervals to determine the effectiveness of the seal.

2. SHIPMENT

a. Remove batteries from instrument (see paragraph 36-C) and wrap the instrument with heavy wrapping paper and seal seams with gummed tape or similar adhesive.

b. Place in fibre-board carton or wooden box large enough to permit at least 3 inches of excelsior or similar packing material between the instrument and sides of the box.

c. For export packing, wrap the instrument in waterproof paper and seal the seams with waterproof glue, or similar sealing compound, before placing it in a wooden box.

APPENDIX II.

TABLE OF REPLACEABLE PARTS

Model 505 Standard Test Set for Transistors

Symbol	Meas. Corp. Part Number	Description
Capacitors		
C1	H-5589	Paper; 0.1 MF; 400 WVDC
C2	H-5589	Paper; 0.1 MF; 400 WVDC
C3	H-5589	Paper; 0.1 MF; 400 WVDC
C4	H-5589	Paper; 0.1 MF; 400 WVDC
Jacks		
J1	H-5535	Telephone
J2	H-5535	Telephone
J3	H-5535	Telephone
J4	H-5535	Telephone
J5	H-5535	Telephone
Meter		
M1	H-960	0-200 uA
Resistors		
R1	H-5591-6	Fixed; metal film; 120K ohms, ± 2%; 1/2 W.
R2	H-5591-6	Fixed; metal film; 120K ohms, ± 2%; 1/2 W.
R3	H-5591-5	Fixed; metal film; 60K ohms, ± 1%; 1/2 W.

Symbol	Meas. Corp. Part Number	Description
Resistors - Cont.		
R4	H-5591-4	Fixed; metal film; 15K ohms, ± 1%; 1/2 W.
R5	H-5774	Fixed; WW; 10.2 ohms, ± 0.1 ohm.
R6	H-5774	Fixed; WW; 10.2 ohms, ± 0.1 ohm.
R7	H-5591-2	Fixed; metal film; 500 ohms, ± 1%; 1/2 W.
Switches		
S1	H-5776	Rotary, 2 Pos., 2 Sec.
S2	H-5777	Rotary, 2 Pos., 3 Sec.
S3	H-5778	Rotary, 6 Pos., 3 Sec.
S4	H-5779	Rotary, 4 Pos., 4 Sec.
S5	H-5780	Rotary, 3 Pos., 1 Sec.
S6	H-5590	Lever, 2 Pos.

APPENDIX III

BIBLIOGRAPHY

A. PERIODICALS.

1. J. Bardeen & W.H. Brattain "Physical Properties Involved in Transistor Action", Bell System Tech. J., 28, 239, 1949.

2. H.T. Mooers, "Low Frequency Noise In Transistors", Proc. NEC, 5, 17, 1949.

3. W. Shockley, "Holes and Electrons", Physics Today, III, 16, 1950.

4. R.L. Wallace, Jr.,"Duality, A New Approach to Transistor Circuit Design", Proc. IRE, 39, 702, 1951.

5. A. Coblenz & H.L. Owens "Variations of Transistor Parameters with Temperature", Proc. IRE, 40, 1472, 1952.

6. R.F. Shea, "Transistor Operation: Stabilization of Operating Points", 40, 1435, 1952.

7. W. Shockley, "Transistor Electronics: Imperfections, Unipolar and Analog Transistors", 40, 1289, 1952.

8. G. Knight, R.A. Johnson & H.B. Holt, "Measurement of Small Signal Parameters of Transistors", Proc. IRE, 41, 983, 1953.

9. W.E. Morrow, Jr., "Measurement of Transistor Parameters by CRO and other Means", Convention Record of IRE, Instr II, 45, 1953.

10. R.F. Shea, "Transistor Application Fundamentals", Electrical Engineering, 73, 360, 1954.

11. H.T. Mooers, "Recent Investigations of Power Transistor Characteristics", Minneapolis-Honeywell Research Center, Hopkins, Minn.

B. BOOKS.

1. W. Shockley, Electrons & Holes in Semiconductors, Van Nostrand, New York, 1950.

2. R.F. Shea, et al, Principles of Transistor Circuits "Wiley", N.Y., 1953.

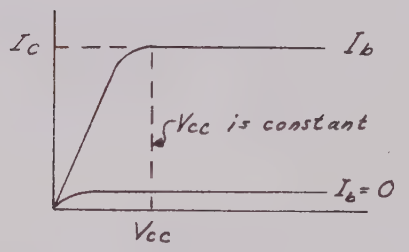
3. R.F. Shea, Transistor Audio Amplifiers, Wiley, N.Y., 1955.

C. MEASUREMENTS NOTES.

1. "Transistor Measurements", Number 8, Measurements Corp., 1955.

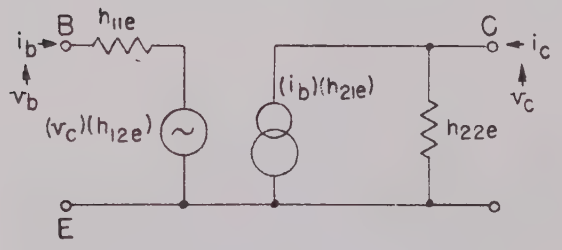
APPENDIX IV

DEFINITIONS OF TECHNICAL TERMINOLOGY AS USED IN THIS MANUAL.

Symbol	Terminology	Definition
b	Incremental Current Gain (or Incremental D.C. Current Gain)	Incremental D.C. Current Gain is defined as follows: $b = \frac{\Delta I_c}{\Delta I_b} = \frac{I_{c2} - I_{c1}}{I_{b2} - I_{b1}}$ when V_{cc} is constant. See Fig. 3 and Para. 21.
B	D.C. GAIN (or D.C. Current Gain)	Sometimes called "large signal gain" or "D.C. Beta". D.C. Current Gain is defined as follows: $B = \frac{I_c}{I_b}$ or $B = \frac{I_c - I_{ceo}}{I_b}$ when V_{cc} is constant. 
B_s	D.C. Saturation Current Gain	D.C. Saturation Current Gain is defined as follows: $B_s = \frac{I_{csat} - I_{ceo}}{I_{bx}}$ See Fig. 4 and Para. 24.
G_m	Intrinsic Transconductance	The four-terminal network is one means of representing a transistor. The relationship between input and output voltages and currents can be analyzed by mathematical methods, i.e., short-circuited admittances, open-circuited impedances, or hybrid combinations.

Symbol	Terminology	Definition
G_m (Cont.)		The low-frequency "T equivalent circuit" and the "h parameter equivalent circuit" are described by four elements or parameters while the low-frequency "hybrid pi equivalent circuit" is described by five parameters. An idealized relationship infers that these parameters can be determined easily from the appropriate d-c characteristic curve. One of the hybrid parameters is called, G_m, or "intrinsic transconductance". G_m is expressed in mhos. G_m is related to the d-c operating condition of a transistor. Knowledge of G_m is useful in making first-order transformations between the common-base T equivalent circuit and the hybrid pi equivalent circuit, and, furthermore, is used as a "figure of merit" in analyzing the high-frequency performance of a transistor. For the purpose of this manual, G_m is defined as $G_m \cong (.039)\ I_c$ mhos in which I_c is in milliamperes since the I_c scale of the Model 505 is calibrated in milliamperes. It is convenient to use the following approximation of G_m: $G_m \cong \frac{1}{r_e} \cong \frac{h_{21}}{r_{b'e}}$ mhos
h_{11e} h_{12e} h_{21e} h_{22e}	Low-frequency "h" parameters of the "h parameter equivalent circuit" common-emitter configuration.	h_{11e} = input impedance of the common-emitter stage with the output short circuited $h_{11e} = \frac{\partial V_b}{\partial I_b}\Big\vert V_c$ is constant

Symbol	Terminology	Definition
		h_{12e} = feedback factor of the common-emitter stage = ratio of open-circuit base voltage and applied collector voltage $= \left.\frac{\partial V_b}{\partial V_c}\right\vert$ I_b is constant
		h_{21e} = small-signal current gain, or current amplification factor (Beta factor) of the common-emitter stage = the ratio of collector current and applied base current with the collector short circuited (zero incremental or signal voltage) $= \left.\frac{\partial I_c}{\partial I_b}\right\vert$ V_c = constant
		h_{22e} = output admittance of the common-emitter stage with the base open circuited $= \left.\frac{\partial I_c}{\partial V_c}\right\vert$ I_b = constant
		"h parameter equivalent circuit" - common-emitter configuration.



I_b	Base Current	D.C. Base Bias Current of the common-emitter transistor.

Symbol	Terminology	Definition
I_{bx}	Base Bias Saturation Current	D.C. Base Bias Current required to drive a switching (computer) transistor to saturation - See Fig. 4.
I_c	Collector Current	D.C. Collector Current.
I_{csat}	Collector Saturation Current	D.C. Collector Current when a switching transistor is driven to the saturation or "ON" condition.
I_{cbo}	Collector Current with the emitter open-circuited.	Collector Current when emitter is D-C open-circuited.
I_{ceo}	Collector Current with the base open-circuited.	I_{ceo} is defined as the d.c. flowing in the collector-emitter circuit when the base is open-circuited (when base current is zero). Sometimes it is called collector cut-off current with the base open. Physically, a graph of I_{ceo} vs collector voltage would be the first curve on a family of I_c - V_c characteristic curves (common-emitter stage); that is, I_{ceo} is the curve on the I_c - V_c characteristic when the d.c. base bias current, I_b, is zero. I_{ceo} is temperature sensitive (since saturation current is a component of I_{ceo}). Hence, the magnitude of this current, or the spacing between the I_{ceo} curve and the voltage axis will vary with ambient temperature.
I_e	Emitter Current	D-C Emitter Current.

Symbol	Terminology	Definition
R_b	Base biasing resistor	Base biasing resistor.
$r_{b'e}$	A hybrid parameter	An input parameter of the "hybrid pi equivalent circuit".
r_e	Emitter forward resistance	r_e is the forward resistance of the emitter-base diode. $r_e \cong \frac{25}{I_e} \cong \frac{KT}{qI}$ Graphically, r_e may be obtained from the appropriate common-emitter characteristic as $r_e = \frac{\partial V_b}{\partial I_c}$ when I_b is constant
R_{EXT}	Base bias resistor for obtaining Saturation Base Current	External base biasing resistor, R_{EXT}, required to obtain saturation base current (for switching transistors operating in the common-emitter configuration).
SWISTOR	SWISTOR	An abbreviation for SWitching transISTOR.
V_b	Base Voltage	D-C Base Voltage (as measured or obtained from the V_b - I_b characteristic of the common-emitter transistor).
V_c	Collector Voltage	D-C Collector Voltage.
V_{cc}	Collector Supply Voltage	D-C Collector Supply Voltage. (Second subscript letter may be omitted in cases when no confusion will result).
V_{cx}	Collector Saturation Voltage	The D-C Voltage between collector and circuit return point for a switching transistor operating properly in the "ON" or saturation condition in the common-emitter configuration. (See Fig. 4).

APPENDIX V

RECAPITULATION OF PROCEDURE FOR MAKING BASIC MEASUREMENTS ON TRANSISTORS USING MEASUREMENTS CORP. MODEL 505 STANDARD TEST SET FOR TRANSISTORS

1. Turn selectors S1, S2, S3, and S4 to counterclockwise positions. Place selector S5 on SHORT-X40 position.

2. Install batteries, observing proper polarity (loosen the four screws on front panel, pull it forward out of case, connect battery leads, and replace front panel).

3. Press S6 to CHECK BATTERY (meter pointer deflects to BAT.).

4. Place PNP transistors in the PNP "REF" or "TEST" position, and NPN transistors in the NPN "REF" or "TEST" position.

5. Move selectors S1, S2, S3, and S4 from left to right, as indicated below to perform basic tests.

   a. Move S1 to REF or TEST to choose transistor for test.

   b. Move S2 to PNP or NPN to choose transistor type.

6. Tests for Short-Circuited Junctions.

   a. Move selector S3 to E-C SHORT (S4 MUST be on LEAK CUR. and S5 on SHORT-X40).

   b. If pointer deflects into the red arc marked SHORT, the transistor has excessive leakage current; if pointer deflects to the solid red area marked SHORT, the transistor has a short-circuited junction. IN EITHER CASE, PERFORM NO ADDITIONAL TESTS.

   c. If the pointer deflection is steady and below the red ball on the arc, the transistor is satisfactory and the tests below can be performed.

7. LEAKAGE CURRENT TESTS (defined as the current flowing in the emitter-collector circuit with the base open; sometimes called collector cut-off current with the base open).

   a. If test 6-c (above) is O.K., place S3 on 6V and leave S4 on LEAK CUR. The leakage current is indicated on the meter scale in microamperes. Multiply the scale reading by 40 to obtain the magnitude of the leakage current - S5 must be in the SHORT-X40 position.

      Example: If the scale reading is 2.3 microamperes the leakage current is (2.3)(40) = 92 microamperes.

b. The 6-volt LEAK CUR. test is a standard test.

c. Place S3 on 12V to obtain the leakage current at a higher collector voltage (providing the transistor is rated for such a collector voltage). Multiply the scale reading by X40, as above, to obtain the magnitude of the leakage current.

8. D.C. GAIN TEST.

a. Place selector S3 on 6V and selector S4 on D.C. GAIN.

b. The D.C. GAIN (sometimes called D.C. Beta) is indicted on the collector current scale of the meter. For the 6V position, multiply the scale reading by 20 to obtain the value of the D.C. GAIN.

Example: With S3 on 6V and S4 on D.C. GAIN, a collector current of 3.3 milliamperes is obtained. The D.C. GAIN is

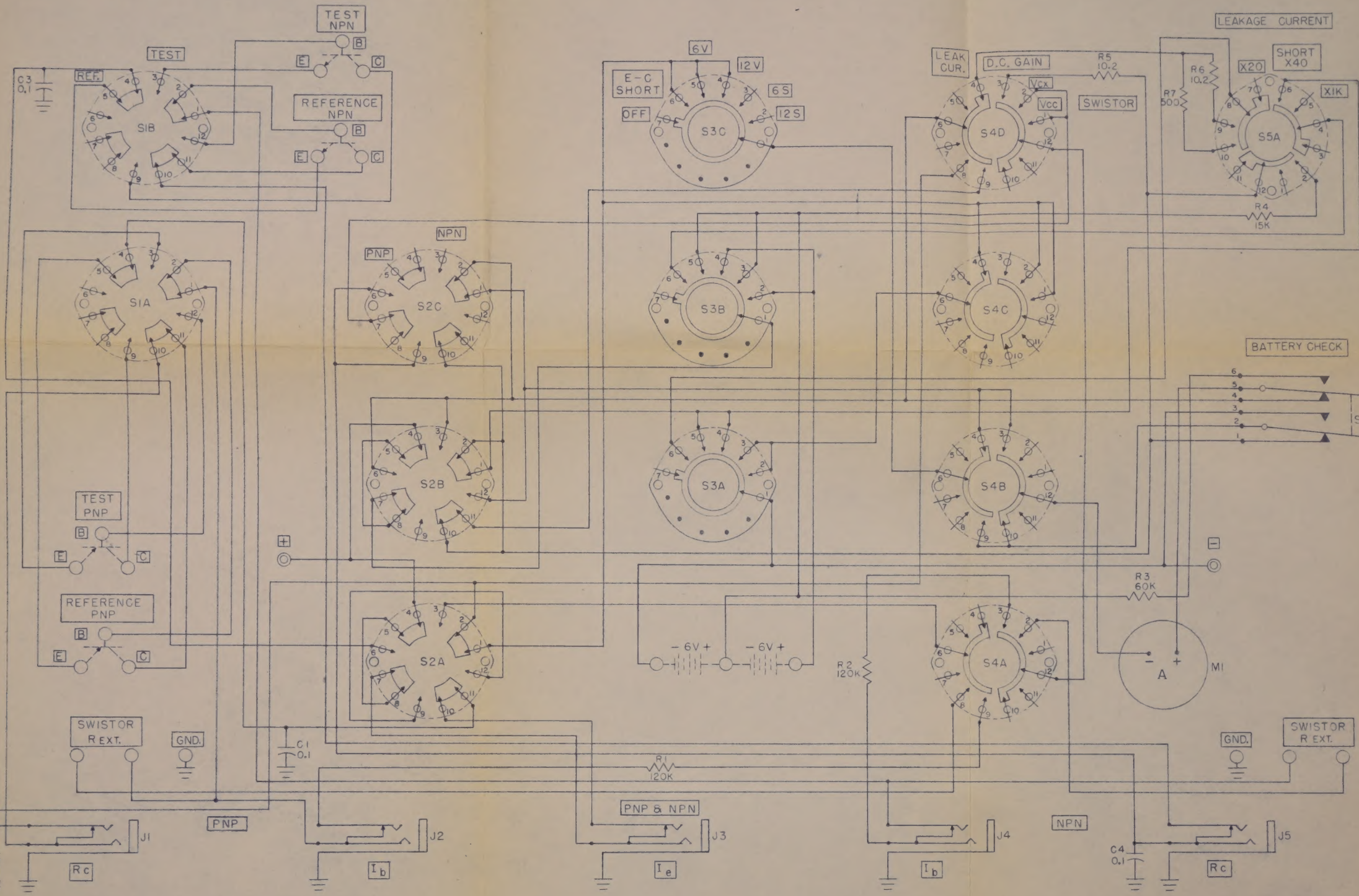
$$B = (3.3)(20) = 66$$

c. D.C. GAIN may be measured at 12 d.c. volts providing the transistor is rated for the higher voltage. Move S3 to 12V, note the scale reading and multiply by 10 to obtain the value of the d.c. gain.

Example: With S3 on 12V and S4 on D.C. GAIN, the measured collector current is 7.5 milliamperes. The D.C. GAIN is

$$B = (7.5)(10) = 75$$

9. See instruction manual for information on the measurement of additional transistor parameters.



NOTE: - 1 - K=1000
- 2 - RESISTORS, EXCEPT R-5, R-6, 0.5 WATT.
- 3 - ALL RESISTORS IN OHMS
- 4 - ALL CAPACITORS IN MICROFARADS
- 5 - SWITCHES SHOWN WITH KNOB IN EXTREME COUNTER-CLOCKWISE POSITION
- 6 - SWITCHES & TERMINALS VIEWED FROM FRONT
- 7 - "A" SECTIONS AT KNOB END
- 8 - BOXED CAPTIONS [XXXX] ARE FRONT PANEL MARKINGS

SCHEMATIC DIAGRAM
MODEL - 505

C-5761-B

MEASUREMENTS

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